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RESEARCH MEMORANDUM

EXPERIMENTAL INVESTIGATION OF EXTREME INTERNAL FLOW TURNING AT THE COWL LIP OF AN AXISYMMETRIC INLET AT A MACH NUMBER OF 2.95

By Kenneth C. Weston and Kenneth L. Kowalski

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

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RESEARCH MEMORANDUM

EXPERIMENTAL INVESTIGATION OF EXTREME INTERNAL FLOW TURNING AT THE COWL LIP OF AN AXISYMMETRIC INLET AT A MACH NUMBER OF 2.95

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SUMMARY

An experimental investigation of the pressure-recovery performance of a fixed-geometry, two-cone, low-drag inlet was made at a Mach number of 2.95. Low drag was achieved by use of an internally cylindrical cowl employing rapid flow turning that was within 4° of the wedge angle for shock detachment. Various boundary-layer bleed slots were used in an attempt to control throat flow separation on the centerbody. Throat bleed in the vicinity of the centerbody shoulder was necessary to control flow separation sufficiently to allow attachment of the internal lip shock wave. A total-pressure recovery of 0.62, corresponding to a kinetic energy efficiency of 0.915, was measured at a mass-flow ratio of 0.97 with throat bleed.

Calculations on a ramjet cycle indicate a net propulsive thrust that is 10 percent greater than the thrust possible with conventional fixed-geometry axisymmetric external-compression inlets having higher pressure recoveries.

INTRODUCTION

As the range of interest in supersonic flight shifts to higher flight speeds, the necessity of optimizing the over-all inlet performance of the air-breathing engine becomes increasingly important. The intelligent selection of the optimum inlet configuration requires careful evaluation of many interrelated factors of which pressure recovery and cowl drag are most significant. If for a fixed-geometry inlet all other factors are presumed to be equal and little influenced by changes in design, the problem is then reduced to the balancing of pressure recovery against cowl drag. Such a balance is necessary since, in general, the highest recoveries obtained with fixed-geometry axisymmetric external-compression inlets have been achieved with high-cowl-drag configurations.

There are several indications that performance losses due to appreciable reductions in pressure recovery can be overcome by decreases in cowl drag. For instance, reference 1 indicates that a one-cone low-drag configuration was competitive at a Mach number of 3.85 with a two-cone inlet and an isentropic inlet on a specific fuel consumption or range basis. Furthermore, ramjet net propulsive thrust calculations at a Mach number of 2.95 indicate that inlets having low cowl drag are comparable with or better than inlets having much higher pressure recoveries achieved by use of a relatively high angle cowl.

An axisymmetric external-compression inlet with low cowl drag produces an internal shock wave originating at the cowl lip. This internal shock must eventually either be reflected or cancelled at the centerbody surface. In doing so, a significant interaction with the centerbody boundary layer usually results that is aggravated by its presence near or in a region of adverse pressure gradient. As indicated by references 1 and 2, separation of the centerbody boundary layer and concomitant pressure-recovery losses are the usual consequences of the severe throat conditions.

In order to determine the severity of the penalties associated with internal-shock reflection and the general desirability of extreme cowl-lip turning in an axisymmetric high-compression inlet, an experimental program was initiated. An inlet model was designed and tested in the NACA Lewis 1- by 1-foot variable Mach number tunnel at a Mach number of 2.95. Performance data in the form of pressure-recovery and mass-flow measurements were obtained.

SYMBOLS

The following symbols are used in this report:

A	area, sq in.
A_K	theoretical minimum area for cowl shock attachment
C	percent of maximum contraction, A_e-A_{th}/A_e-A_K
C_D	drag coefficient (based on A_0)
C_F	net propulsive thrust coefficient, $C_{F,i} - C_D$
$C_{F,i}$	internal thrust coefficient (based on A_0)
M	Mach number
m	mass-flow rate

P total pressure

P/P_0 total-pressure recovery

p static pressure

γ ratio of specific heats

θ_l cowl-position parameter

Subscripts:

e inlet entrance station normal to average flow direction

j jet exit station

th throat

0 free-stream conditions

1 diffuser discharge station

APPARATUS AND PROCEDURE

The cowl drag of an external-compression inlet is governed largely by the rate of turning of the internal flow near the cowl lip. A high rate of turning allows the reduction of the external cowl angle and a resultant reduction in cowl drag. Flow turning through an oblique-shock wave that has a wave angle equal to the detachment angle of the reduced Mach number flow field ahead of the cowl lip serves as the maximum allowable rate of turn for an inlet lip. The inlets reported here utilized this type of flow turning with the exception that a 4° margin of safety from the detachment angle was used to assure that detached-shock spillage would not occur as a result of excessive cowl-lip compression.

To illustrate the reduction in cowl angle possible and to simplify machining, an internally cylindrical cowl was selected for use with two two-cone centerbodies. The cone angles were then selected as those giving maximum theoretical pressure recovery at a free-stream Mach number of 2.95 without exceeding the desired internal wave angle. A 17.5° half-cone angle followed by a 10° increase in angle was used. Figures 1 and 2 show a sketch of the supersonic inlet and a photograph of the inlet in the tunnel, respectively. The two centerbodies and single cowl were scaled to mate with an existing subsonic-diffuser model support system (fig. 3).

When the flow field corresponding to the inlet configuration chosen is mapped, a very rapid centerbody turn is found to be necessary to avoid exceeding the Kantrowitz-Donaldson contraction criterion. Two centerbodies were designed that differed essentially only in sharpness of centerbody shoulder (designated as centerbodies I and II). When the centerbodies are matched with the cowl they are designated as inlets I and II. At the design cowl position parameter ($\theta_l = 27.8^{\circ}$) these inlets have the area ratios and percentages of maximum contraction shown in the following table along with those of a hypothetical inlet of maximum contraction.

Inlet	Area ratio A_{th}/A_e	Maximum contraction, C, percent
I	0.828	98.1
II	.877	70.2
Maximum contraction	.8247	100.0

While the percent of maximum contraction C is high, the actual area reduction is small as a result of the low supersonic entrance Mach number that allows only a small area decrease. Centerbody and cowl coordinates for both inlets are given in figure 1.

The locations of six flush slots for centerbody boundary-layer removal are shown in figure 1. For identification purposes these are designated A to F. Equally spaced holes were drilled at the bottom of the slots to connect to the interior of the centerbody. The slots were filled and smoothed when not used. Bleed air was ducted through the centerbody and out through the three centerbody support struts which were vented to free-stream static pressure. No independent control of the bleed flow was exercised.

Measurements in the form of pressure-recovery and mass-flow data were taken for both inlets. The arithmetic mean of the pressures obtained from an area-weighted rake was taken as the engine-inlet total pressure. The mass-flow ratio was calculated by using a calibrated choked plug and the total-pressure recovery, assuming no change in total pressure between rake and plug.

The experimental tests were conducted in the NACA Lewis 1- by 1-foot variable Mach number tunnel at a Mach number of 2.95 and a simulated pressure altitude of 55,000 feet. The tunnel total temperature was maintained at $100^{\circ}\pm5^{\circ}$ F and the dewpoint at $-20^{\circ}\pm10^{\circ}$ F. The test Reynolds number was 2.72×10^{6} based on the maximum model diameter of 4.5 inches.

RESULTS AND DISCUSSION

Inlet Performance

The performance of inlets I and II is shown in figure 4 for the "slot D open" and the "all slots filled" cases. Included in the figure are schlieren photographs of the external-shock-wave-structure during supercritical operation. Comparison of the all slots filled photographs with those with slot D open shows the failure of the no-bleed configuration to swallow the detached shock wave ahead of the cowl lip, while the wave is clearly attached in the slot D open case. Since slot D is located in the minimum-area section, its success in permitting swallowing of the lip shock is not a result of mass-flow removal ahead of the throat; hence, the inlet is not physically overcontracted.

Several investigations, including those previously cited (refs. 1 and 2), have observed that boundary-layer separation at or near a throat can result in choking of the passage. Therefore, it is felt that boundary-layer removal through slot D acts as a controlling influence on separation in the throat caused by shock-wave - boundary-layer interaction and/or rapid centerbody turning. This is further emphasized by examination of table I, which lists bleed combinations tested in conjunction with each of the two inlets. Results indicated that none of the bleed combinations that excluded slot D allowed attachment of the cowl shock. It may then be reasonably concluded that boundary-layer control located in the throat in the proximity of the centerbody shoulder is a requisite for cowl-shock attachment with this type of inlet.

The sensitivity of inlet I to bleed-slot location is graphically illustrated in figure 5. The pressure-recovery - mass-flow ratio curves and the accompanying schlieren photographs showing supercritical operation indicate the ineffectiveness of slots E and F in swallowing the cowl detached shock even though slot E was located only 0.08 inch downstream of the rear of slot D. Slots D, E, and F were similar in every respect except axial position. The peak pressure recovery was found to decrease with bleed-slot distance from the centerbody shoulder, a further indication of the desirability of the location of the bleed slot close to the centerbody shoulder.

A summary of the performances of inlets I and II with various bleed combinations is shown in figure 6. Peak pressure recoveries obtained varied from 61 to 66 percent, all obtained with subcritical operation at mass-flow ratios from approximately 0.80 to 0.90. Pressure recoveries as high as 0.62 (corresponding to a kinetic energy efficiency of 0.915) were obtained with a mass-flow ratio of 0.97 (both inlets, slot D open, fig. 6(d)). Inspection of the slot D open schlieren photographs of figure 4 shows that a portion of the mass-flow loss is due to oblique-shock spillage. Furthermore, since no control of the bleed flow was exercised, optimum bleed flow may not have been used.

The performances of inlets I and II are compared in figures 4 and 6. Practically identical performance was obtained with both inlets for the no-bleed case. With few exceptions, the peak recoveries obtained with inlet I were slightly higher than those obtained with inlet II. The performance of the two inlets was only marginally different, which indicates that the sharpness of the centerbody shoulder was not as important as favorable bleed location.

In general, the minimum stable point of the inlet varied from capture mass-flow ratios of 0.76 to 0.95. As indicated by figure 4, the use of slot D moved the minimum stable point of both inlets from a mass-flow ratio of about 0.95 for no bleed to approximately 0.88 for the slot D open condition. Furthermore, the minimum stable mass-flow ratios of figure 6 indicate that the use of bleed flow through any of the slots resulted in an improvement in flow stability over the no-bleed case.

Total-pressure distortions obtained with both inlets were on the order of 0.05. These low distortions should not necessarily be considered a result of the supersonic inlet design since an abnormally long subsonic diffuser was employed. In general, the total-pressure profiles dipped at the axis of the inlet because of the boundary-layer buildup on the long centerbody in the presence of an adverse pressure gradient.

Figure 7 shows the effect of change of tip projection on the performance of inlet II with slots B and D open. No performance gains were realized by decreasing the cowl-position parameter. On the other hand, the decrease of peak recovery with increases in tip projection was small. Increases in the cowl-position parameter that resulted in overcontraction gave poor recoveries which were not recorded.

Evaluation of Inlet Performance

Two methods were used to calculate the theoretical pressure-recovery performance of the inlets reported here. The conventional shock structure calculation made consisted of an evaluation of the total-pressure changes through the external shock waves and isentropic compression internally to a normal shock at the minimum area. The pressure recovery was also calculated by the method of reference 3 by assuming a sharp centerbody shoulder and by using calculated cone surface pressures. This method is a solution of the momentum and continuity equations for a zero angle cowl in the absence of frictional effects. The results are tabulated in the following table and are compared with the measured results obtained at a mass-flow ratio of 0.97:

Calculation	Pressure recovery, P/P_0	
	Inlet I	Inlet II
Conventional shock structure	0.72	0.71
Method of ref. 3	.65	.64
Measured recovery at $m/m_0 = 0.97$	.62	.62

The measured recovery at a mass-flow ratio of 0.97 is well estimated by the calculation described in reference 3 which takes into account supersonic turning losses. The difference between the experimental recovery and that predicted by the method of reference 3 represents frictional and subsonic-diffuser losses. Therefore, it is felt that comparison of the experimental with the theoretical pressure recoveries indicates that with proper boundary-layer control no severe shock - boundary-layer interaction losses are incurred by the use of a low-angle cowl at a Mach number of 2.95.

The dependence of the internal thrust coefficient of a hypothetical ramjet engine designed for a free-stream Mach number of 2.95 on the inlet pressure recovery is shown in figure 8. Also shown are curves of theoretical drag coefficients and the resulting propulsive thrust coefficients for two-cone and isentropic inlets with no internal compression. These curves were obtained for inlets with internal cowl-lip surfaces alined with the stream of the compressed flow field and represent a range of external lip angles from 20° to 34°. The case of the internal flow alined with the cowl lip was selected because it provides a well-defined relation between the drag and pressure recovery when the empirical drag correlation of reference 4 is used. It should be emphasized that this case represents a lower limit for the performance of a well-designed axisymmetric inlet. Any efficient attempts to reduce cowl drag by internal cowl-lip compression should result in better propulsive thrust performance than that defined by the theoretical curves. A discussion of the calculations is presented in the appendix.

Examination of figure 8 indicates that the propulsive thrust performance of the isentropic inlets selected is essentially independent of the pressure-recovery level over the range of values selected. It may be noted that the propulsive thrust coefficient curves for the isentropic and two-cone inlets coincide in the lower pressure level, but the two-cone inlet suffers a rapid decrease in thrust at the higher recoveries. This difference between the curves results from the fact that, as the external cowl-lip angle approaches the two-dimensional shock detachment value, large increases in pressure recovery are obtained for the isentropic inlet, while only small increases are obtained with the two-cone inlet.

Figure 8 also includes points representing the results of several experimental investigations. Thrust coefficients were evaluated in each case that employed the same ramjet calculations as for the theoretical curves described previously.

The drag coefficient for the assumed ramjet configuration using the inlet of the present report was evaluated by applying linearized theory to a 3° conical nacelle with the nozzle exit-inlet capture-area ratio required by the experimental pressure recovery. Comparison of the resulting propulsive thrust coefficient with the theoretical inlet curves shows the gain in net propulsive thrust possible with an inlet employing the internal reflected-shock principle as compared with the conventional high-angle cowl inlet.

The Mach 3 performance of the inlet of reference 5 is indicative of the experimental results obtainable with a two-cone all-external-compression inlet of rather basic and conventional design with no-bleed flow. This point is shown for comparison with the theoretical two-cone inlet curve (fig. 8).

The gains made possible by employing a translating spike for inlet starting in conjunction with the internal reflected-shock principle are indicated by the point of reference 6 (fig. 8). This performance was achieved with a single-cone, translating spike, high internal-compression inlet, which used two internal cowl reflected shocks to obtain low cowl drag and high pressure recovery.

The experimental drags reported in references 5 and 6 were adjusted slightly to make them compatible with the nozzle exit-inlet capture area ratio required by the assumed engine and the experimental pressure recovery. No drag corrections due to bleed or supercritical cowl-lip spillage were considered since all three experimental points operated at approximately the same mass-flow ratio ($m/m_0 = 0.97$). This would slightly reduce the thrust coefficients shown.

It may be concluded that, with the low-drag type inlet having throat bleed, propulsive thrust coefficients may be obtained that are as much as 10 percent higher than those obtainable with an inlet having the internal cowl lip alined with the compressed stream. Further additional gains are available if variable geometry in the form of spike translation for starting is allowed.

SUMMARY OF RESULTS

A two-cone inlet with a low-drag cowl was tested at a Mach number of 2.95. The low-drag cowl was achieved by rapid internal flow turning of 4° less than the wedge angle for shock detachment. The results are as follows:

1. A comparison of theoretical pressure-recovery calculations with the experimental data indicates that with proper boundary-layer control no severe shock - boundary-layer interaction losses were incurred by the use of the extreme cowl-lip angles at this Mach number.

2. Calculations at Mach 2.95 indicate that, with the low-drag-type inlet having throat bleed, propulsive thrust coefficients may be obtained that are as much as 10 percent higher than those obtainable with an inlet having its internal cowl-lip alined with the compressed stream.

3. The use of throat bleed in the vicinity of the centerbody shoulder controlled flow separation sufficiently to allow attachment of the internal lip shock. Use of throat bleed 0.08 inch downstream of the rear of the shoulder bleed slot did not allow attachment.

4. Application of a theory which is a solution of the momentum and continuity equations for inlets with zero angle cowls estimated quite closely the experimental pressure recoveries obtained.

5. A total-pressure recovery of 0.62 (corresponding to a kinetic energy efficiency of 0.915) was achieved at a mass-flow ratio of 0.97 with throat bleed. Peak pressure recoveries as high as 0.66 were obtained with subcritical operation and high bleed flows corresponding to mass-flow ratios from approximately 0.80 to 0.90.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
Cleveland, Ohio, February 4, 1958

APPENDIX - DISCUSSION OF CALCULATIONS

In the calculation of the theoretical propulsive thrust coefficient - pressure-recovery curve of figure 8, a number of assumptions and restrictions were made.

A hypothetical ramjet engine was assumed that had a fixed capture area and full capture mass flow. A subsonic diffuser-exit Mach number of 0.2 was assumed, and a combustor total-temperature ratio of 3.0 was used with a fuel-air ratio of 0.05. The combustor was assumed to be of constant cross-sectional area with $\gamma = 1.4$ prior to combustion and $\gamma = 1.3$ at the combustor exit and in the exit nozzle. The exit nozzle was cut off by employing the empirical formula given in reference 7:

$$\frac{A_j}{A_1} = 1 + 0.55\left[\left(\frac{A_j}{A_1}\right)_{p_0=p_j} - 1\right]$$

The inlet configurations used were two-cone and isentropic inlets having no internal compression and internal lip angles alined with the stream of the centerbody flow field. In all cases a 3° thickness angle was assumed for the cowl lip. For the two-cone inlets the compression angles were selected as those giving maximum theoretical recovery at selected internal lip angles. For the isentropic inlets, the pressure recovery is described uniquely by the flow angle at the focal point. The tabulated Mach numbers and flow angles of reference 8 were used to obtain this recovery. In both cases, a 5-percent diffuser total-pressure loss was assumed.

The empirical curve of reference 4 relating cowl-lip angle, nozzle exit-inlet area ratio, and pressure drag coefficient for cowls of elliptical contour was employed to obtain theoretical cowl pressure drags. A laminar friction drag coefficient of 0.01 was used in all cases.

REFERENCES

1. Connors, James F., and Woollett, Richard R.: Performance Characteristics of Several Types of Axially Symmetric Nose Inlets at Mach Number 3.85. NACA RM E52I15, 1952.

2. Connors, James F., and Woollett, Richard R.: Some Observations of Flow at the Throat of a Two-Dimensional Diffuser at a Mach Number of 3.85. NACA RM E52I04, 1952.

3. Meyer, Rudolph C.: Flow-Turning Losses Associated with Zero-Drag External Compression Supersonic Inlets. NACA TN 4096, 1957.

4. Samanich, Nick E.: Pressure Drag of Axisymmetric Cowls Having Large Initial Lip Angles at Mach Numbers from 1.90 to 3.88. NACA RM E57G24, 1957.

5. Connors, James F., Wise, George A., and Lovell, J. Calvin: Investigation of Translating-Double-Cone Axisymmetric Inlets with Cowl Projected Areas 40 and 20 Percent of Maximum at Mach Numbers from 3.0 to 2.0. NACA RM E57C06, 1957.

6. Obery, Leonard J., and Stitt, Leonard E.: Performance of External-Internal Compression Inlet with Abrupt Internal Turning at Mach Numbers 3.0 to 2.0. NACA RM E57H07a, 1957.

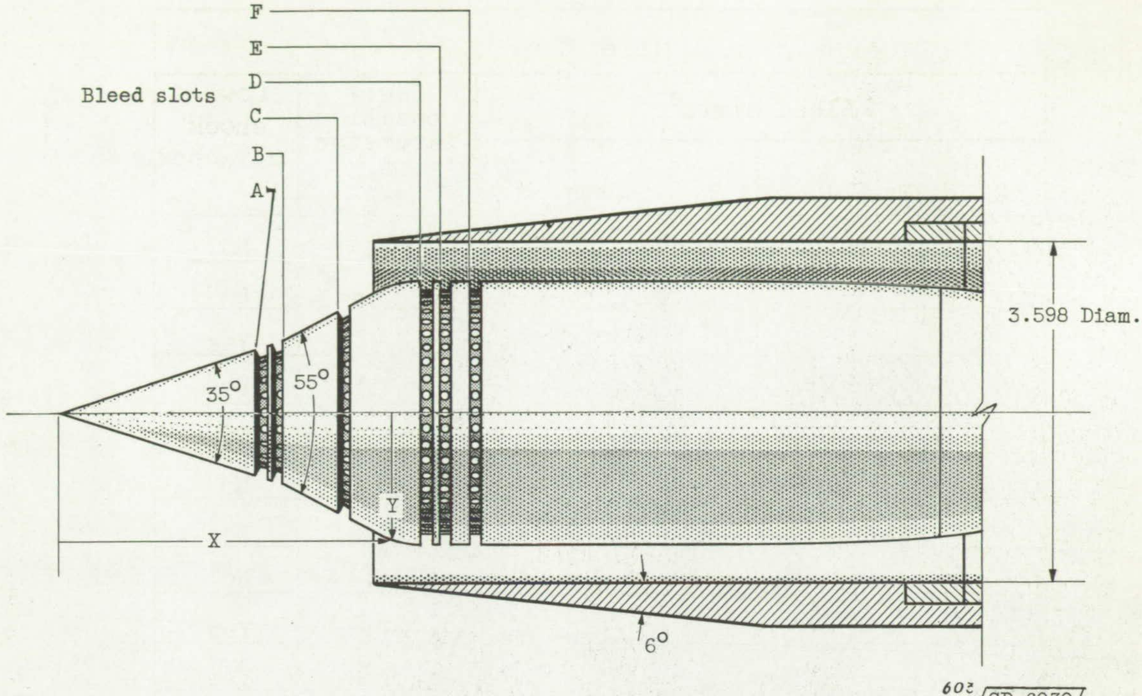
7. Weber, Richard J., and Luidens, Roger W.: Analysis of Ram-Jet Engine Performance Including Effects of Component Changes. NACA RM E56D20, 1956.

8. Connors, James F., and Meyer, Rudolph C.: Design Criteria for Axisymmetric and Two-Dimensional Supersonic Inlets and Exits. NACA TN 3589, 1956.

TABLE I. - INLET CONFIGURATIONS TESTED

Bleed slots[a] A	B	C	D	E	F	Cowl-position parameter, θ_l, deg	Cowl shock attached
Inlet I							
Closed	Open	Open	Closed	Open	Closed	27.8	No
Closed	Open	Closed	Closed	Open	Closed	27.8	No
Closed	Open	Open	Open	Open	Closed	27.8	Yes
Closed	Closed	Closed	Open	Closed	Closed	27.8	Yes
Closed	Closed	Closed	Closed	Closed	Closed	27.8	No
Closed	Closed	Closed	Closed	Closed	Open	27.8	No
Closed	Closed	Closed	Closed	Open	Closed	27.8	No
Closed	Open	Closed	Closed	Open	Closed	27.8	No
Closed	Open	Closed	Open	Closed	Closed	27.8	Yes
Open	Open	Closed	Open	Closed	Closed	27.8	Yes
Closed	Closed	Open	Open	Closed	Closed	27.8	Yes
Closed	Open	Open	Open	Closed	Closed	27.8	Yes
Inlet II							
Closed	Closed	Closed	Closed	Closed	Closed	27.8	No
Closed	Closed	Closed	Open	Closed	Closed	27.8	Yes
Closed	Closed	Open	Open	Closed	Closed	27.8	Yes
Closed	Open	Open	Open	Closed	Closed	27.8	Yes
Closed	Closed	Closed	Open	Open	Closed	27.8	Yes
Closed	Closed	Open	Open	Open	Closed	27.8	Yes
Closed	Closed	Closed	Open	Open	Open	27.8	Yes
Closed	Open	Closed	Open	Open	Closed	27.8	Yes
Closed	Open	Closed	Open	Closed	Open	27.8	Yes
Closed	Open	Closed	Open	Closed	Closed	27.8	Yes
Closed	Open	Closed	Open	Closed	Closed	27.6	Yes
Closed	Open	Closed	Open	Closed	Closed	27.4	Yes

[a]Bleed slots: ▭ open; ▨ closed.



Centerbody I		Centerbody II	
X, in.	Y, in.	X, in.	Y, in.
0	0	0	0
2.40	.756	2.40	.756
3.50	1.311	3.50	1.311
3.60	1.351	3.60	1.361
3.70	1.375	3.70	1.380
3.80	1.387	5.00	1.380
3.90	1.390	7.00	1.370
7.00	1.390	8.75	1.360
8.00	1.382	9.12	1.348
8.75	1.370	9.50	1.320
9.12	1.348		
9.50	1.320		
Bleed slot	Distance to leading edge of slot	Bleed slot	Distance to leading edge of slot
A	2.12	A	2.12
B	2.40	B	2.40
C	3.00	C	3.00
D	3.90	D	3.72
E	4.10	E	4.01
F	4.44	F	4.34

Figure 1. - Schematic diagram of supersonic inlet with inlet coordinates.

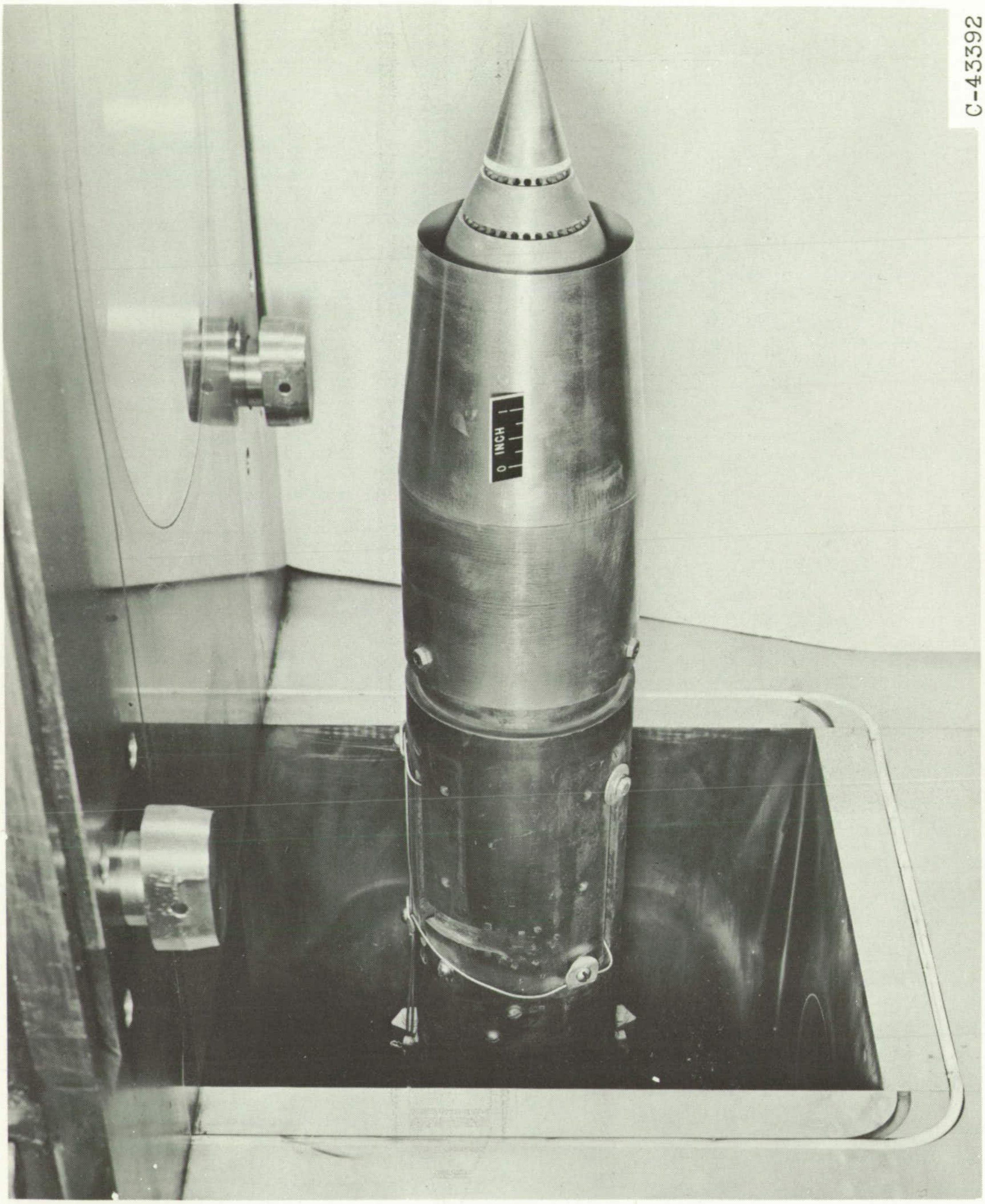


Figure 2. - Inlet I in variable Mach number tunnel.

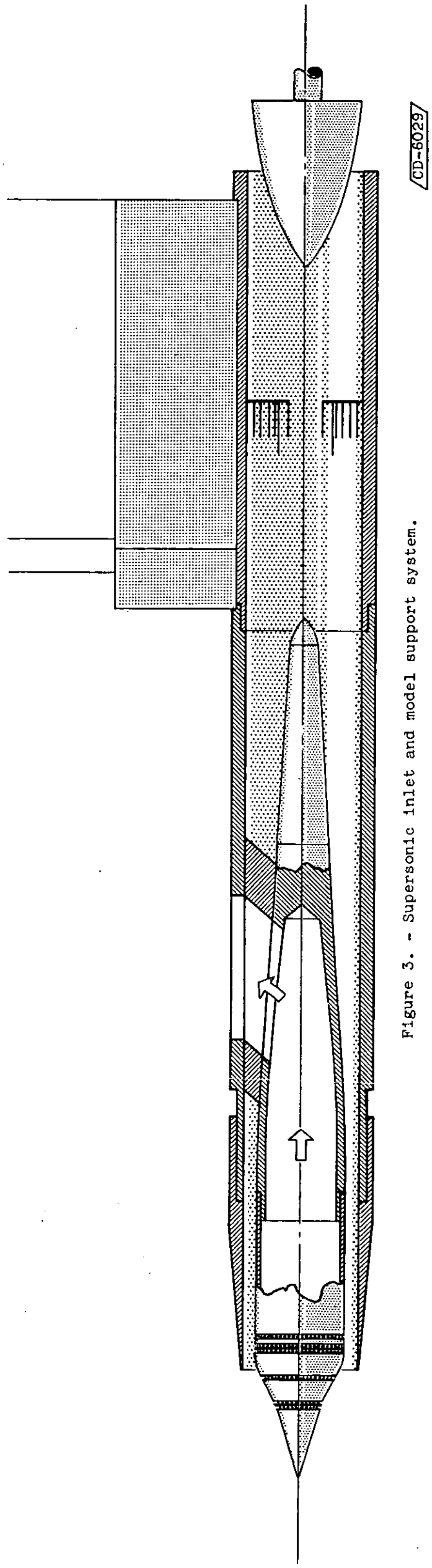


Figure 3. - Supersonic inlet and model support system.

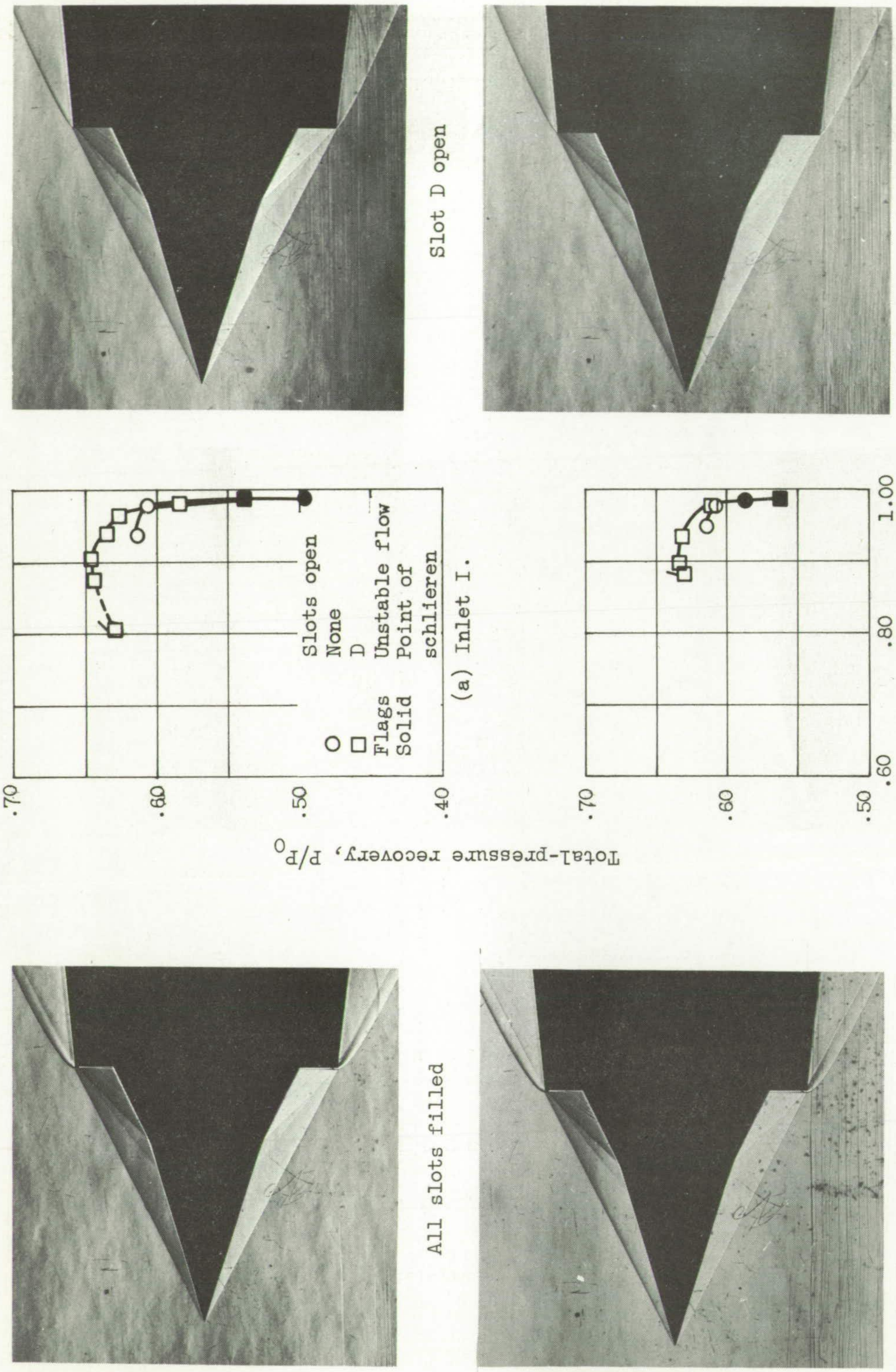
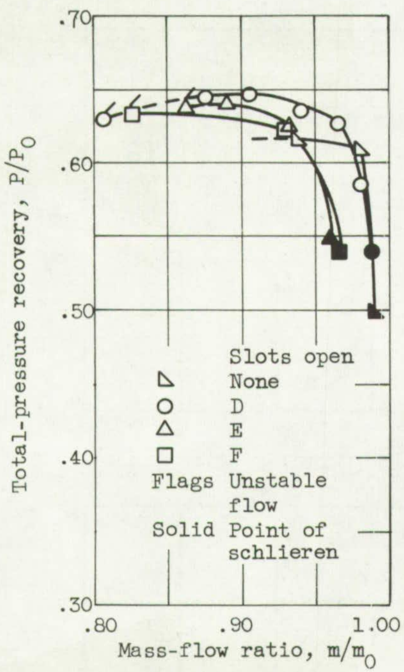
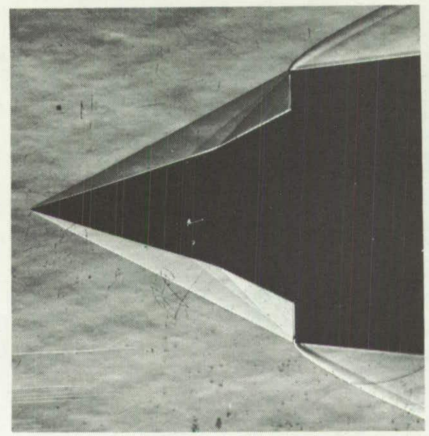
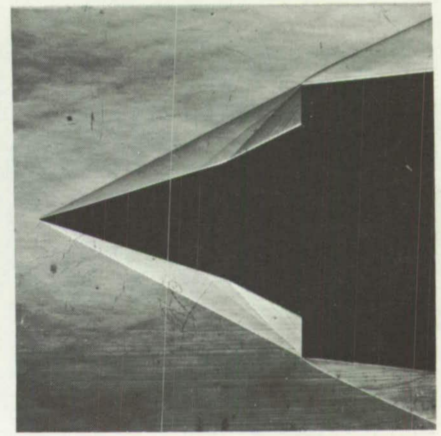


Figure 4. - Performance of inlets I and II with slot D open and with all bleed slots closed. Free-stream Mach number, 2.95; cowl-position parameter, 27.8°.

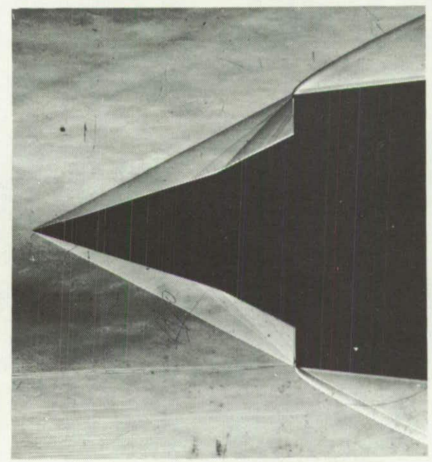




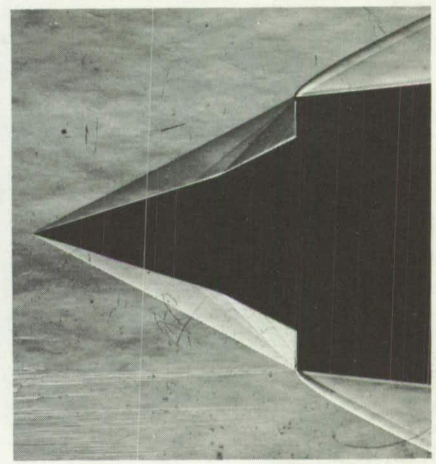
All slots filled



Slot D open



Slot E open



Slot F open

C-47011

Figure 5. - Effect of throat bleed slot location on pressure recovery for inlet I. Free-stream Mach number, 2.95; cowl-position parameter, 27.8°.

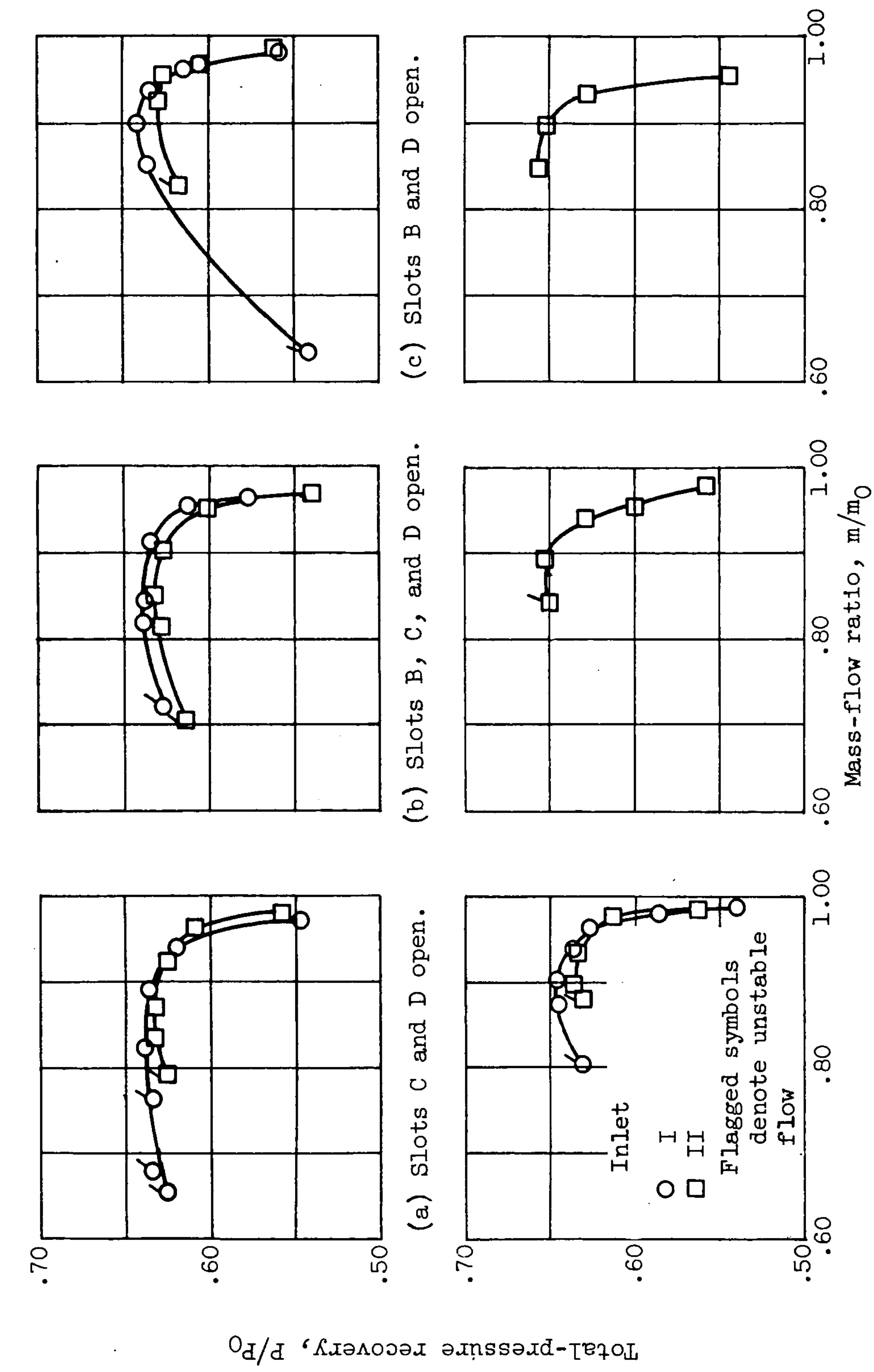


Figure 6. - Summary of performance of inlets I and II with various bleed combinations. Free-stream Mach number, 2.95; cowl-position parameter, 27.8°.

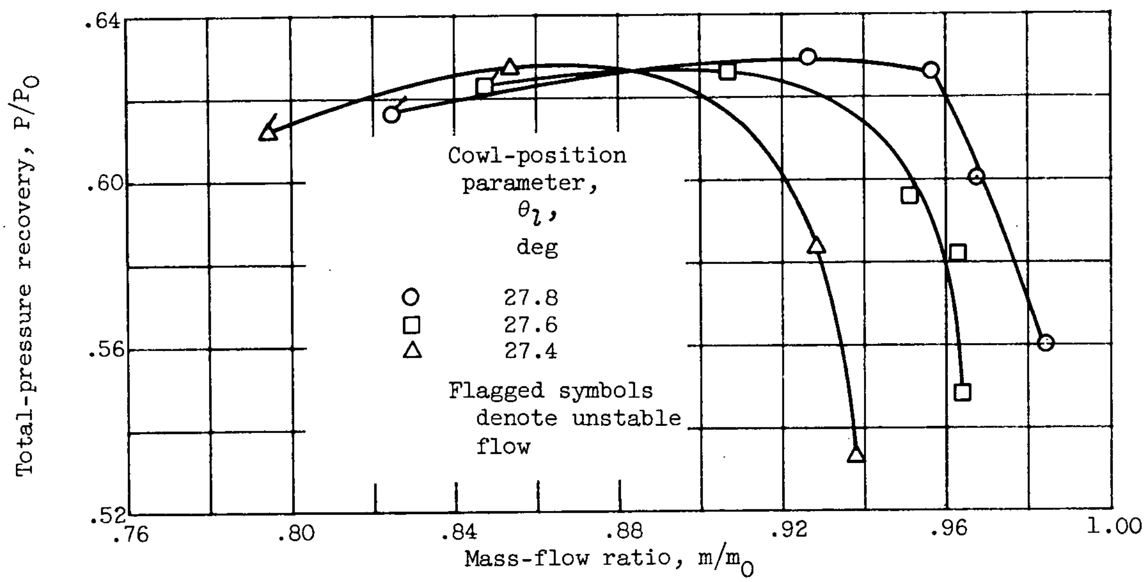


Figure 7. - Effect of tip projection on inlet II performance. Free-stream Mach number, 2.95; bleed slots B and D open.

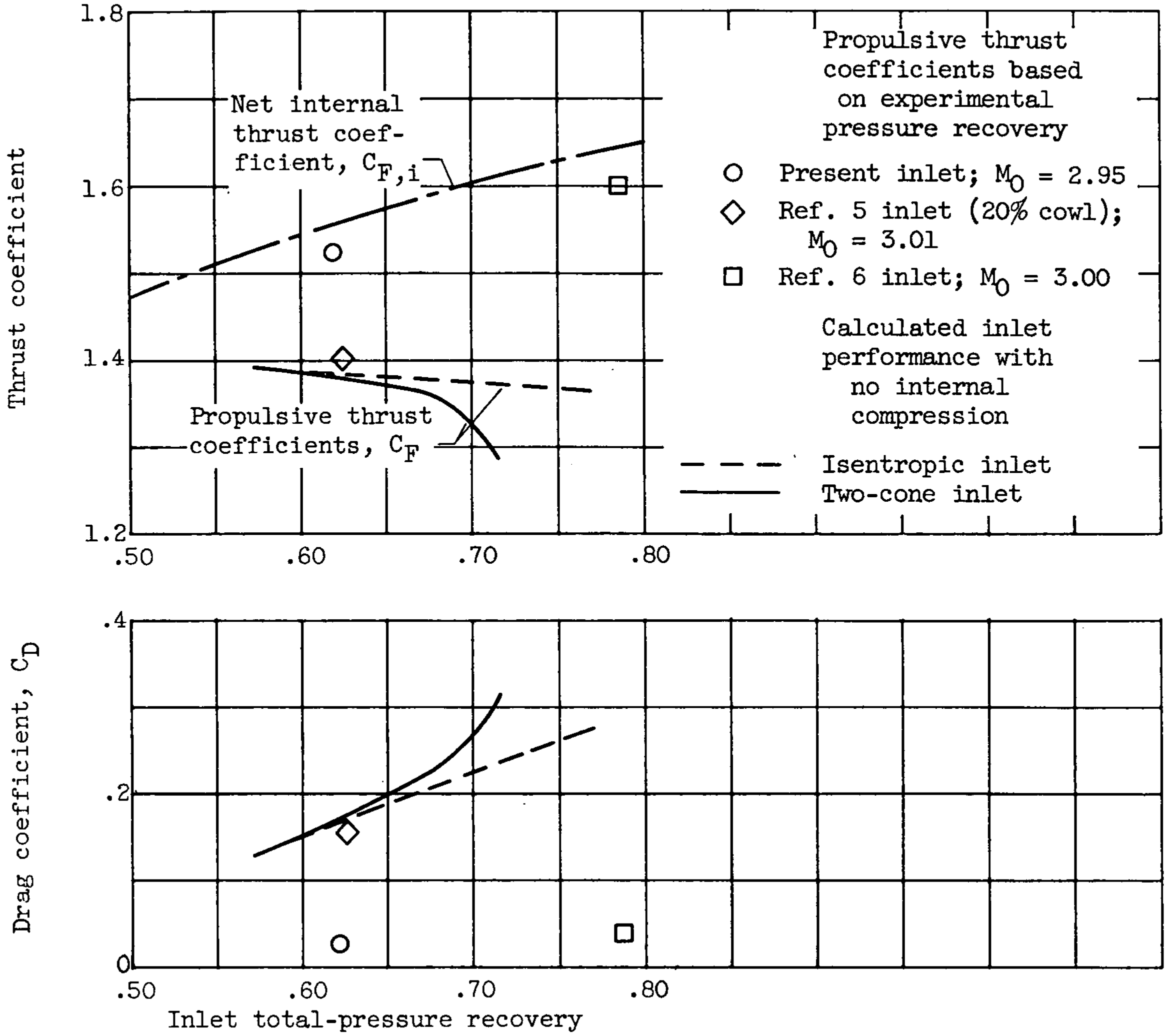
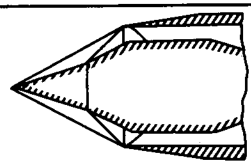
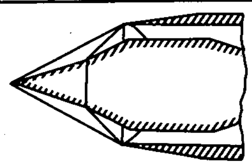
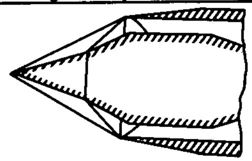
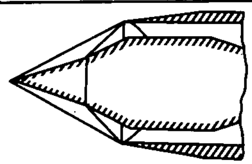


Figure 8. - Performance of a ramjet engine as function of inlet pressure recovery. Free-stream Mach number, 2.95; engine total-temperature ratio, 3.0; diffuser-discharge Mach number, 0.20; fuel-air ratio, 0.05.

NACA - Langley Field, Va.

NOTES: (1) Reynolds number is based on the diameter of a circle with the same area as that of the capture area of the inlet.

(2) The symbol * denotes the occurrence of buzz.

Report and facility	Description			Test parameters				Test data				Performance		Remarks
	Configuration	Number of oblique shocks	Type of boundary-layer control	Free-stream Mach number	Reynolds number × 10^{-6}	Angle of attack, deg	Angle of yaw, deg	Drag	Inlet-flow profile	Discharge-flow profile	Flow picture	Maximum total-pressure recovery	Mass-flow ratio	
CONFID. RM E58A27a Lewis 1- by 1-Foot Variable Mach Number Tunnel	 Fixed-geometry two-cone inlet	3	Flush slots in various locations	2.95	2.17	0	0				√	0.66	0.99-0.76*	Internally cylindrical cowl generated an oblique shock to turn flow rapidly and achieve low cowl drag. Higher net propulsive thrust coefficients are obtained than with conventional inlets having higher pressure recoveries.
CONFID. RM E58A27a Lewis 1- by 1-Foot Variable Mach Number Tunnel	 Fixed-geometry two-cone inlet	3	Flush slots in various locations	2.95	2.17	0	0				√	0.66	0.99-0.76*	Internally cylindrical cowl generated an oblique shock to turn flow rapidly and achieve low cowl drag. Higher net propulsive thrust coefficients are obtained than with conventional inlets having higher pressure recoveries.
CONFID. RM E58A27a Lewis 1- by 1-Foot Variable Mach Number Tunnel	 Fixed-geometry two-cone inlet	3	Flush slots in various locations	2.95	2.17	0	0				√	0.66	0.99-0.76*	Internally cylindrical cowl generated an oblique shock to turn flow rapidly and achieve low cowl drag. Higher net propulsive thrust coefficients are obtained than with conventional inlets having higher pressure recoveries.
CONFID. RM E58A27a Lewis 1- by 1-Foot Variable Mach Number Tunnel	 Fixed-geometry two-cone inlet	3	Flush slots in various locations	2.95	2.17	0	0				√	0.66	0.99-0.76*	Internally cylindrical cowl generated an oblique shock to turn flow rapidly and achieve low cowl drag. Higher net propulsive thrust coefficients are obtained than with conventional inlets having higher pressure recoveries.

Bibliography

These strips are provided for the convenience of the reader and can be removed from this report to compile a bibliography of NACA inlet reports. This page is being added only to inlet reports and is on a trial basis.